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Utilization of Beetle-Killed Southern Pine

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Introduction

Each year bark beetles kill southern pine trees over millions of acres of commercial timberland. The southern pine beetle (*Dendroctonus frontalis* Zimmermann) is most damaging. While preventive strategies are preferred, salvage removal of infected and recently killed timber is the most widely used direct control treatment. Removal efforts often include healthy trees from a buffer strip to make the harvesting more cost effective and insure the removal of all infested trees. Timber buyers and mill managers often question the suitability of beetle-killed timber for wood products manufacture. Recent research results have shown that if the trees can be harvested and processed soon after attack, they can be profitably utilized for a wide range of wood products. The following information summarizes the utilization potential of beetle-killed pines.

The Southern Pine Resource

The southern pines occur on more than 100 million acres of commercial forest land in the United States either as a mixture with other species or as pure stands. The bulk of the resource is located south of the Mason-Dixon line and east of the Great Plains (Koch 1972). There are 10 species of southern pines, but loblolly (*Pinus taeda* L.), shortleaf (*P. echinata* Mill.), longleaf (*P. palustris* Mill.), and slash (*P. elliottii* Engelm.) make up most of the total inventory.

As a source of raw material for the wood industry, the southern pines are an important national resource. The trees can be grown rapidly in pure stands over a broad range of sites, and the physiography and environmental conditions favor their growth, utilization, and marketing. The wood from southern pines has many desirable properties. It has outstanding strength for lumber and plywood. The color and fiber strength make it desirable for paper and fiber products, and it is easily dried and treated with preservatives.

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Southern Pine Beetle Damage

Southern pines, as a group, are susceptible to many insect and disease organisms, but the most prevalent of these is the southern pine beetle (SPB). In some years, beetle outbreaks occur throughout the 13-State southern pine region; in others, the damage is limited to a few widely scattered locations. Probably no other insect is of more concern to forest managers in the South than the southern pine beetle.

Once infestations have been detected, several methods can be used to stop the spread of the pest. Chemical control, pile-and-burn, cut-and-leave, and salvage removal are the recommended methods. Landowners usually prefer salvage removal because some of the losses can be recovered if they can sell the timber. Cut-and-leave is sometimes used where infestations are small and scattered or are located in inaccessible areas. The material may be salvaged later even though it has been on the ground for several weeks. Landowners or forest managers using salvage or cut-and-leave methods seek to halt infestation spread and to utilize the material before it deteriorates. Chemical control and pile-and-burn are seldom used because of the expense of chemical treatment and possible environmental concerns in the use of either method.

Frequently, mill managers will purchase small quantities of beetle-killed material and blend it in with their usual supply of green logs, but they are hesitant to purchase large quantities. Reasons generally given for this reluctance to harvest and process beetle-killed timber are: 1) Difficult and hazardous to harvest, 2) costly and difficult to process, 3) difficult to dry uniformly, especially when mixed with green lumber, 4) reduces lumber grade and yield, 5) has a restricted market, and 6) the material is often difficult to grade when standard lumber grades are used because of variation in stage of deterioration.

Even at reduced stumpage prices, it is sometimes difficult to find a buyer for beetle-killed timber, particularly when there are numerous woodborer and ambrosia beetle holes and initial decay in the outer wood layers.

Figure 1—Class A trees.

Timber Characteristics

Physical Appearance

Various changes in external appearance occur when beetle-killed southern pine trees are left standing. It is generally thought that tree appearance can be linked to the stage of deterioration of the wood caused by various insects and fungi. Following is a description of the changes that can be expected in the tree after insect attack.

Crown—The rate of color change (or fading) in the crown is related to the time of year the trees are attacked as well as local climatic conditions. Foliage color changes from green to yellow to red. Color changes are followed by total loss of needles, then small twigs and branches, large branches, and tops as the degree of deterioration intensifies. It is common for all levels of deterioration to be present in an infestation since the trees are normally attacked at different times and the spot may spread over a period of weeks or months. Levi (1981) makes a generalization that appearance of beetle-killed trees is a better guide to their potential utilization than the length of time they have been dead. Two major appearance classes have been suggested for judging the usefulness of beetle-killed southern pine trees for various wood products:

> *Class A*—Trees ranging from those with needles to those with no needles but a branch and twig structure still relatively intact, and, where foliage exists, color ranging from green to yellow green to red (fig. 1).

Class B—Trees ranging from those with smaller branches and twigs breaking off to those with completely broken tops and generally no foliage (fig. 2).

Figure 2—Class B trees.

Stem—Stems of discolored trees usually show small yellowish-white masses of pitch, called pitch tubes, marking the points where adult beetles have bored directly through the bark. Sometimes pitch tubes do not form and the only evidence of attack may be reddish-brown boring dust in bark crevices and on spiderwebs and foliage at the base of the tree. Close examination of the bark will often reveal numerous small holes about the size of birdshot caused by young adults emerging from the bark. Soon after beetle attack, the bark also loosens and is easy to peel from the stem. Many timber markers and procurement people use the presence or absence of bark as a guide for determining the suitability of SPB-killed trees for wood products, but this is not reliable since the rate of bark loss varies widely.

Inner bark—The appearance of the inner bark of beetle-killed trees is characterized by winding S-shaped galleries. Eggs are deposited in niches on either side of these galleries and hatch into small grubs. The curved shape of SPB galleries clearly distinguishes them from those made by any other pine bark beetle in the South (fig. 3). The excavations of beetles and their larvae in the cambium and inner bark crisscross one another and contribute to the death of the tree through the girdling action.

Figure 3—S-shaped galleries of southern pine beetle.

Wood—The wood in standing SPB-attacked trees usually becomes heavily stained from blue-stain fungi carried by the southern pine beetle. The tree's water conducting system is plugged by the fungi and this, when combined with the girdling action in the cambium, is certain to result in death of the tree. The tendency of blue-staining fungi to associate with wood parenchyma tissue of the sapwood (usually found in the wood rays) creates an appearance of radial streaks or wedge-shaped areas fanning out in the sapwood. These characteristic patterns are easily seen on the ends of sawlogs or pieces of pulpwood. Numerous small pin holes and larger sized borer holes often give the wood a distinctive and pleasing appearance for some specialty wood product uses. These holes are created by other beetles (ambrosia beetles and woodborers) boring into the sapwood after bark beetle attack and are most numerous in the outer portions of the sapwood. Figure 4 illustrates the appearance of lumber with distinctive patterns that would be typical of material obtained from the outer sapwood of such trees. The presence or absence of these patterns would depend on the stage of infestation by the bark beetles and associated insects.

Figure 4—Appearance of lumber produced from beetle-killed trees.

Wood Properties

A number of wood properties are of particular importance in determining the suitability of beetle-killed southern pine for various products.

Specific gravity—Because specific gravity is so useful in predicting other properties and projecting the value of products, it is of primary interest in utilization decisions. The rate of deterioration of SPB-killed trees is quite variable and depends on season of the year, local climatic conditions, and the speed with which infested trees are harvested after detection of insect attack. Barron (1971) reported the specific gravity reductions for increment cores taken from spring-infested trees (with monthly sampling May through October) and summer-infested trees (with monthly sampling July through December) in east Texas (see tabulation below).

Summer-infested trees, felled and allowed to remain on the ground, showed the greatest reduction in specific gravity. In contrast, Walters (1982) reported no apparent reduction in specific gravity of pie-shaped wedges cut from standing and felled trees or from small, clear lumber specimens taken from beetle-killed trees dead for up to 360 days.

Walters and Weldon (1982c) reported the following average weights of wood and bark per cubic foot of material from trees killed by the SPB in summer:

Time after kill	Standing trees	Felled trees
Days	--------*Lbs./cu. ft.*--------	
0 (green)	64.35	—
45	47.10	46.49
90	41.20	44.22
180	45.49	53.85
360	38.34	44.85

The average weight per cubic foot was greater for cut-and-leave (felled) trees than for the standing trees except for the 45-day group. The greater densities for felled trees reflect differences in moisture content. And since the moisture contents were not given, the data cannot be analyzed for changes in specific gravity.

Moisture content—Approximately half the total weight of green southern pine wood is accounted for by water. When expressed as a percentage of dry wood, this translates into a moisture content of 100 percent. Moisture affects the weight, strength, shrinkage, machinability, and other important properties of wood. In beetle-killed trees, the comparison of weight-scaling factors (normally used for green trees) is of primary concern.

		Reduction in specific gravity for trees dead for		
Infestation time	Condition	1 mo.	3 mo.	6 mo.
			Percent	
Spring (with monthly sampling May-Oct.)	Standing	0.92	2.77	5.55
	Felled	1.69	5.08	10.17
Summer (with monthly sampling July-Dec.)	Standing	1.23	3.70	7.40
	Felled	2.60	7.79	15.58

Substantial amounts of water are lost almost immediately after a tree dies, but the amount of drying depends on the length of time since death, environmental conditions, and location in the tree. Barron (1971) reported that moisture content is highest at the base and decreases with increasing height in beetle-killed trees. The opposite is true in green southern pines. In green trees, moisture content increases with height, and upper logs always contain a higher percentage of moisture than butt logs (Koch 1972). Patterson et al. (1983) reported on moisture content for beetle-killed trees by time since death and location in the tree. The data indicated rapid loss of moisture in the upper stem within the first 2 months, but substantial moisture remained at the base of the tree. Barron (1971) reported that the moisture content of beetle-killed trees dropped 22 to 53 percent within the month after attack, and the loss was slow thereafter.

Data collected by the author from beetle-killed trees in southwest Mississippi further verified this rapid loss of moisture.[2] The trees were harvested approximately 3 months after infestation was detected by aerial survey. Moisture content samples were collected from each tree at the top of the butt log (25 feet) and at the merchantable top. Tree crown condition and moisture contents (dry basis) were as shown in the tabulation below.

Mechanical strength—Strength properties of small, clear specimens from beetle-killed southern pine have been reported by Sinclair et al. (1979a) and by Walters (1982). These studies indicated a 10-percent reduction in bending strength (modulus of rupture) within 60 days after foliage fade. Modulus of elasticity, an indication of material stiffness, was not as sensitive as modulus of rupture, but some reduction occurred. Mean reductions of 19 percent in modulus of rupture and 11 percent in modulus of elasticity were noted for wood taken from trees standing two full seasons (20 months) after foliage fade in the Piedmont and Coastal Plain of Virginia.

In an east Texas study, Goehring (1980) processed southern pine trees, left dead on the stump for 12 months, into 2 by 6 structural lumber to evaluate the effects of delayed salvage on stress grades. These results revealed that work to maximum load and modulus of rupture properties were significantly reduced by the time the tree had stood on the stump for 1 year. The study revealed that lumber cut from these trees could safely perform as No. 3 grade, but that structural

[2]Woodson, G.E. Cost factors associated with sawing and chipping beetle-killed southern pine. Unpub. Final Report to Southern Region, Forest Pest Management; 1983. 104 p.

Crown condition (color)	Moisture content at top of Butt log	Moisture content at top of Upper log
	Percent	
Green	51.1	41.5
Green-fade (color changing)	36.6	33.0
Red	35.4	28.1
Red-thin (some needles missing)	33.9	29.2
Black (devoid of needles)	32.1	27.6

utilization should be restricted to floor and wall systems in which other members may help share the applied loads. Extreme care should be exercised in placing lumber cut from trees in this stage of deterioration into critical structural applications such as trusses.

Results of toughness tests on beetle-killed southern pine by Sinclair et al. (1979b) indicated that most of the loss in toughness occurred during the first warm season following death of the tree. Reductions of 30 to 40 percent in toughness values at 12 months since foliage fade were reported.

Permeability—The capability of wood to allow passage of fluids under pressure is called its "permeability."Southern pine sapwood is more permeable than most species and, therefore, less troublesome to dry and to treat with wood preservatives. Heartwood is much less permeable than sapwood because most pits in the heartwood are aspirated and because the extractives further block the flow.

It is generally believed that southern pine sapwood infested with blue-stain fungi absorbs more water and preservative than noninfested wood. These fungi obtain their nourishment primarily from the materials stored in parenchyma cells in the sapwood and cause little damage to the cell wall structure. The fungi occupy the ray cells primarily, and the increased permeability is due to a breakdown of ray parenchyma and some direct penetration of the fungal hyphae through tracheid cell walls. Since blue-stain fungi are deposited when the southern pine beetle attacks, utilization guidelines for such material must consider the increased permeability and how it affects the product or process.

Effective utilization of beetle-killed timber requires prompt attention to salvaging the material as soon as possible. This is not always easy to bring about. Beetle infestation sites are often small and scattered, and woodland managers hesitate to send a logging crew to a site for such a small quantity of timber. At other times, mill managers are concerned that beetle-killed timber might cause processing problems.

Harvesting and Storage

It is commonly believed that felling beetle-killed timber is more dangerous for workers than felling sound green timber. While this may be true for material in advanced stages of deterioration, it does not appear to be true in general. This author's observation of a logging operation in a beetle infestation in Mississippi disclosed no substantial breakage during the felling of 100 trees (in various stages of crown condition from green needles to being devoid of needles but having small branches intact). Significant amounts of bark were lost, and in many cases tree-length stems were devoid of bark. This might mean a loss in revenue from bark sales or fuel value for the mill owner, but it does not appear to create unusually hazardous working conditions.

Loss of bark would also be important where logs are stored under waterspray until they can be processed. Brodie and DeGroot (1976) reported weight gains during waterspray storage averaging 21 percent for loads of beetle-killed logs and 10 percent for loads of sound green logs.

Sometimes it becomes necessary to fell beetle-killed trees and leave them on the ground (cut-and-leave). Special circumstances (enough volume and easy accessibility) some-

times make it practical to utilize cut-and-leave material even after it has been left several months. One instance has been noted in central Louisiana where summer-killed trees (June) remained on the ground and were used the following April. The loggers only salvaged the butt log of each tree (32 feet).[3]

In other situations, salvage sales of beetle-killed timber offered by National Forests have drawn no bids. Various reasons are given for this, including poor timber markets or insufficient volume in specific infestations to attract buyers.

Weight Scaling

In the South, much of the short-log logging and stick scaling has been replaced by tree-length logging and weight scaling. Considerable effort has been exerted to develop prediction equations and yield tables for estimating stem weights and sawmill lumber and residue yields from green southern pine. Guttenberg et al. (1960) claimed that scaling by weight promised equal accuracy and greater day-to-day consistency in predicting lumber yields from southern pine sawlogs than scaling by any of the usual log-rule methods. They recognized that individual mills would have to develop their own prediction factors for local conditions and pointed to the following potential advantages of weight scaling:

1. A single objective measurement that can replace multiple scaling by timber growers, loggers, haulers, and mill workers.
2. The elimination of stick scaling's log-by-log computations and opportunities for error.
3. Shorter truck turnaround time at the mill.
4. Feasibility of uncontested spot payment for delivered logs.
5. A stimulus for delivery of green logs, free from stain.
6. Lessening of the risk of physical injury to scalers.

While the above factors may seem to be advantages of weight scaling, the uncertainty of the accuracy in converting weight to any log scale has been a major concern of people marketing logs. Guttenberg et al. (1960) established regression equations for predicting lumber tally from logs of various weights and from truckload weight. The equations were as follows:

Board feet lumber yield =

$$\frac{\text{Log weight}}{9.88} + \frac{(\text{Log weight})^2}{254{,}362} - 10.96$$

1 MBF lumber yield =

$$\frac{\text{Load weight}}{10.17} - 13.44$$

According to their measurements, 7 to 12 pounds of logs are required to produce 1 board foot of green lumber. On a truckload weight basis, a load weight of 10,300 pounds will yield 1,000 board feet of green lumber.

Siegel and Row (1960) developed a prediction equation to determine average weights of rough logs of varying diameters and lengths. Their formula (below) is accurate for logs between 12 and 20 feet in length and up to 22 inches in diameter:

$$\text{Log weight} = 0.371\, D^2 L + 51$$

D = Scaling diameter (inches)
L = Log length (feet)

[3]Personal communication from Forrest Oliveria, Forest Pest Management, Southeastern Area State and Private Forestry, USDA Forest Service.

Prediction equations like the one just shown were developed for fresh logs from a given region and should be used only for rough comparisons. Differences in moisture content of beetle-killed logs make it unwise to apply green sawlog and pulpwood conversion factors to beetle-killed trees. For example, average weight for green loblolly pine per thousand board feet (Scribner log rule) has been reported by Williams and Hopkins (1969) to vary from 12,800 to 14,900 pounds. McNab (1983) reported weights of 10,600 pounds per thousand board feet (Scribner log rule, Form class 78) for beetle-killed loblolly pine sawtimber in northeast Georgia. The moisture content of the beetle-killed stems was 62 percent. If a moisture content of 100 percent (normally found in green loblolly pine) is assumed, McNab's conversion factor would have estimated an average weight of 13,086 pounds per thousand board feet, which is within the range of data reported by Williams and Hopkins (1969) for green sawlogs.

Obviously, the variation in weight-volume relationships is such that accurate predictions can be made only with specific data on moisture and bark content. Wood density varies considerably as specific gravity and moisture content change. For example, weight per cubic foot of southern pine might vary as follows:

	Density of wood at moisture content of			
Specific gravity	100%	80%	60%	40%
O.D. wt., green vol.	*Lbs./cu. ft.*			
0.42	52.4	47.2	41.9	36.7
.46	57.4	51.7	45.9	40.2
.50	62.4	56.2	49.9	43.7
.54	67.4	60.7	53.9	47.2

These specific gravities may not cover the range of values for all southern pines, but they do illustrate the effect of moisture content on density. The species specific gravity average for loblolly and shortleaf pine is generally accepted as 0.47 based on oven dry weight and green volume (Koch 1972).

The literature, as well as logic, indicate that conversion factors between weight and log scales are strongly related to diameter and specific gravity within certain geographic localities (Koch 1972; Siegel and Row 1960). Converting tapered, round logs into square-edged lumber becomes increasingly inefficient as log diameter decreases. Most sawmills measure their efficiency by the number of board feet of lumber produced per cubic foot of log. This is known as a Lumber Recovery Factor (LRF) and varies considerably by mill and log diameter. If a mill manager knows the LRF and log volume in cubic feet, the volume of lumber expected can be calculated. A simple example will illustrate the effects of moisture content on weight-volume relationships. Figure 5 is an expression of the relationship:

$$\text{Weight} = \text{Density} \times \text{Volume}$$

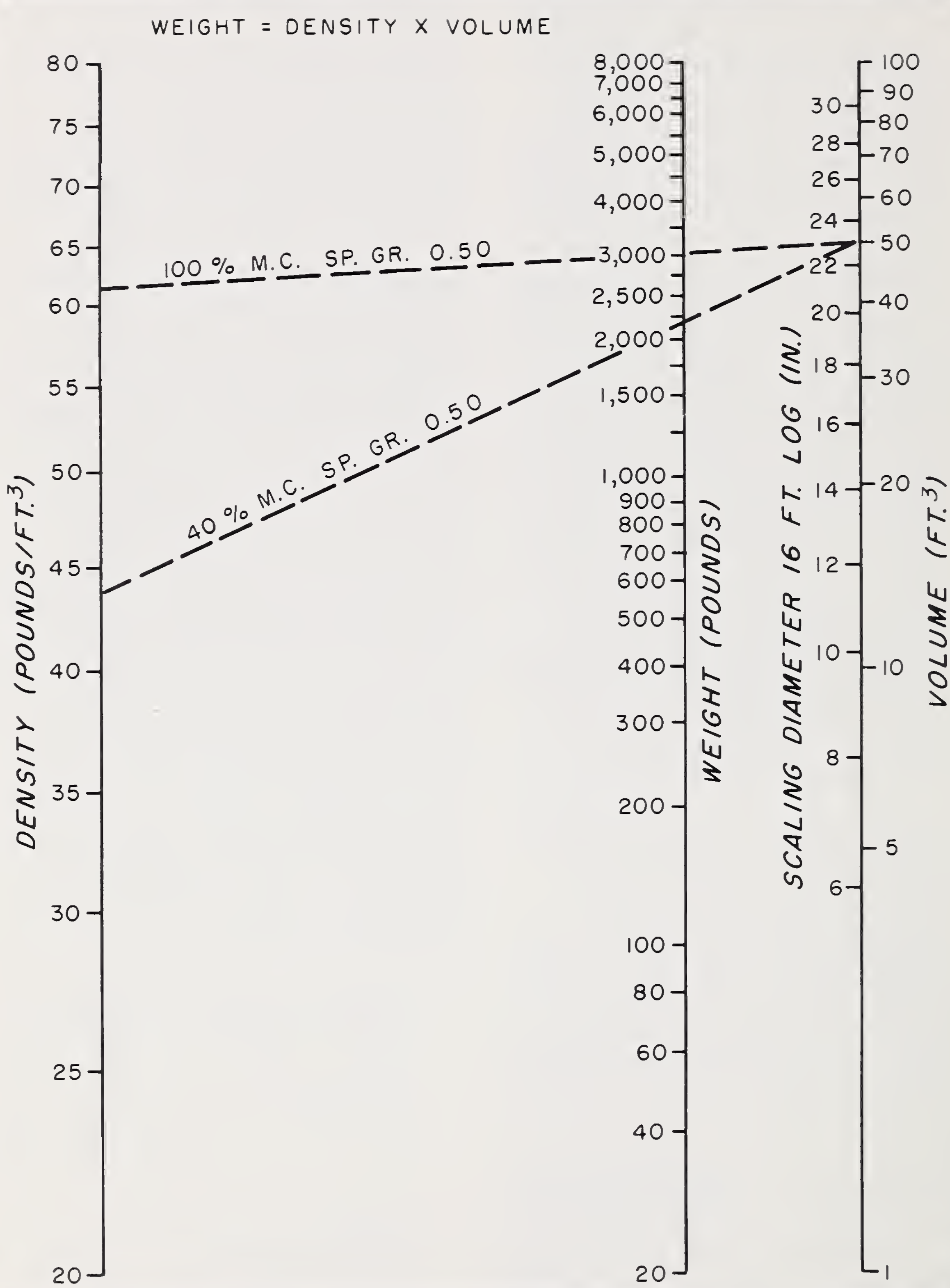


Figure 5—Nomograph for weights of southern pine logs.

This figure provides a rapid method of determining log weight-volume relationships for known wood densities. Assume that typical green southern pine has an average density of 62.4 lbs./cu. ft. (specific gravity 0.50 and moisture content 100 percent), and that a log or a group of logs has a volume of 50 cubic feet. The weight calculation for this example would be 3,120 pounds. Likewise, if the moisture content of beetle-killed timber is only 40 percent, the density drops to 43.7 lbs./cu. ft. and the weight calculation for the same example is only 2,185 pounds. The difference would be approximately 1 ton per cunit (100 cubic feet) and would be of particular concern to the person marketing the logs if the mill were using the normal conversion factor for green logs. Had the mill manager established LRF's for beetle-killed timber, adjustments could be made in the normal weight-scaling conversion or by the process illustrated in figure 5, where density can be adjusted. With the estimated volume, the manager could then make a reasonable estimate of the lumber output.

Milling and Manufacturing

Beetle-damaged timber sometimes creates special processing difficulties at the mill primarily because of property differences with green timber. Many of these problems could be avoided if the material were handled separately. Mill managers typically lump everything together and seldom have enough beetle-killed timber to justify the expense of separation.

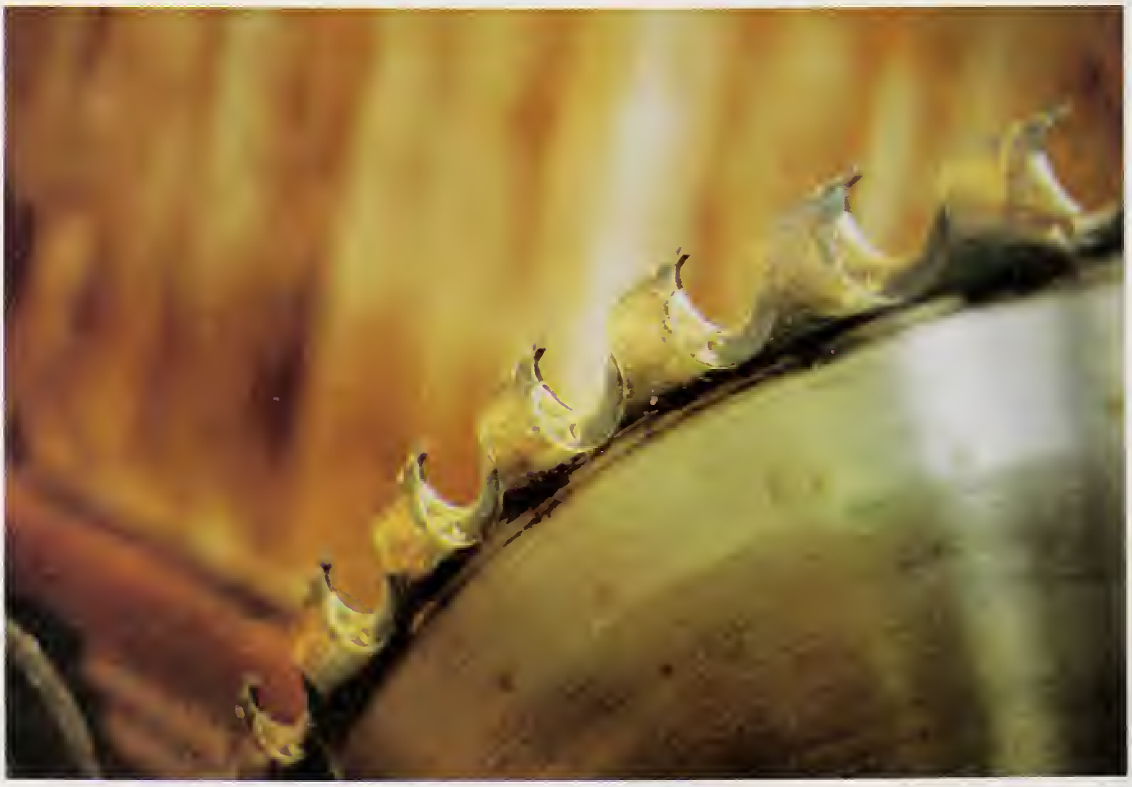
The bark of beetle-killed trees is so easily removed that it may jam conveyors at the debarker. Variation in moisture content may also create major problems. While moisture content of butt logs may equal that of green logs, the upper logs may be so dry that saws overheat and their teeth accumulate residues. (Chipper knives dull at a much faster rate). Figure 6 illustrates the residue buildup on an inserted tooth saw after cutting very dry, beetle-killed logs.

Grading of lumber from beetle-killed trees is more time consuming because of the difficulty in distinguishing between blue-stained and initially decayed wood. Most southern pine mills cut primarily dimension lumber. Since stain is not considered a defect in dimension material, the grader may overlook some evidence of decay. Lumber yields are typically lower from beetle-killed logs because the sawyer cuts larger slabs in order to remove the heavily stained (and possibly decayed) wood contained in the outer sapwood.

Seasoning and Preservation

Widely varying moisture contents in beetle-damaged timber or mixtures of green and beetle-killed timber create substantial problems in the drying process. Material with low moisture content will be over-dried if wet wood is dried to the proper moisture level. Increased permeability of wood with blue-stain means that the wood dries faster than normal wood. This increased permeability also increases the rate at which wood preservatives are absorbed. With energy and chemical costs soaring, kiln operators and wood preservative plants have little margin for inefficiency in energy use for drying or in application of standard preservative treatments.

(A)



(B)

Figure 6—Inserted tooth saw with gum residue from dry (A) and beetle-killed logs (B).

Suitability for Various Products

A major concern regarding the utilization of beetle-killed timber is whether it can be considered a practical and profitable raw material when fresh green material is available. Research studies have provided useful information to indicate that beetle-killed timber can be utilized for numerous wood products if harvesting and processing are accomplished soon after infestation. The following section summarizes information on the suitability of this material for various wood products.

Lumber

Lumber yield and quality decrease with increasing time after beetle attack. The following measures of mill efficiency have been reported from research studies in three States:[4]

Location	Time since beetle attack	Beetle infested logs	Green logs
	Days	------*LRF*------	
Virginia	360	5.8	6.7
Texas	45	5.7	6.4
Mississippi	90	6.8	7.6

It has been noted that mill workers change their sawing practices when processing beetle-killed pine. The sawyer intentionally slabs heavier than normal to remove the outer sapwood, and edging methods are altered. Grade recovery and lumber yield are thus substantially reduced. Walters and Weldon (1982a) reported that trees dead for 90 days in east Texas yielded 75 to 79 percent as much lumber as green sawlogs. Trees dead for 180 to 360 days did not appear economical to utilize. The volume of No. 2 and better lumber produced from trees dead for 90 days or longer is much less than that from green trees.

Table 1 illustrates a comparison of rough green and dry planed (S4S) lumber grades for lumber produced from 327 logs taken from trees with crown conditions varying from green to devoid of needles (black). The differences between 1-inch boards and 2-inch dimension were significant. The volume percentages of boards (1-inch) in each grade remained about the same for the rough green and dry planed gradings, indicating that the lumber was properly graded with regard to stain. The grader did not manage as well with the dimension lumber due to the difficulty in distinguishing the difference between heavy stain and the beginning stages of decay. Since stain is not a defect in dimension lumber, the grader was forced to make a judgment as to which condition existed. The lumber apparently looked much worse in the rough green condition. Grades between rough green and final dry planed material differed considerably. Generally, the rough green grading indicated a lower percentage of No. 1 and a higher percentage of No. 2 lumber than the actual dry-planed grade for lumber from all crown conditions. Lumber taken from the trees with red-thin and black crowns had substantial amounts of heavy stain, and the grader downgraded a high percentage of these to No. 4 because of decay. When these pieces were dried and planed, however, the grades were changed from No. 4 to No. 1 in many cases. It must be noted that lumber is normally graded in the dry-planed condition, and this alleviates much of the problem.

Additional information on dry-planed lumber grade recovery for butt and upper logs from the

[4] Virginia and Texas data reported in Westbrook et al. (1981); Mississippi data reported by Woodson (1983).

Table 1—*Comparison of rough green and dry planed lumber grade by crown color*[1]

Crown color	Surface condition	Boards (1-inch) Grade 1	2	3	4	Dimension (2-inch) Grade 1	2	3	4
		Percent							
Green	Rough	16.3	65.6	15.6	2.5	16.1	65.1	14.6	4.2
	S4S	15.0	68.2	13.5	3.3	43.8	44.6	5.1	6.5
Green-fade	Rough	8.2	72.0	15.4	4.4	16.9	65.1	8.7	9.3
	S4S	4.1	81.0	9.2	5.7	51.0	33.6	7.2	8.2
Red	Rough	10.7	66.2	15.9	7.2	8.9	75.6	4.7	10.8
	S4S	8.1	63.4	22.9	5.6	50.6	36.1	5.7	7.6
Red-thin	Rough	.8	48.2	23.5	27.5	4.8	46.7	9.0	39.5
	S4S	2.5	57.4	22.3	17.8	33.4	35.9	11.3	19.4
Black	Rough	.5	50.3	22.8	26.4	2.6	47.4	7.7	42.3
	S4S	1.6	56.3	13.7	28.4	32.8	28.4	3.9	34.9

[1]Values are expressed as percentages of total lumber within a given thickness.

327-log sample is given in table 2. As expected, butt logs yielded more No. 2 and better lumber than the upper logs, and the effect of knots in the upper logs contributed to a higher percentage of No. 3 lumber. Butt logs generally yielded the highest percentage of No. 4 lumber (indicating presence of decay).

Plywood

Utilization of beetle-killed southern pine for veneer and plywood is feasible for several weeks after attack. Walters and Weldon (1982b) reported that green and beetle-killed trees dead for up to 45 days in east Texas were equal in volume, grade, and type of veneer produced. Plywood recovery factor (PRF = square feet of 3/8-inch plywood per cubic foot of wood input) for green and 45-day kill class combined was 15.25. The PRF for 90-and 180-day kill class combined was 13.53 (approximately 11 percent less recovery than for green and 45-day kill class). The lower PRF for SPB-killed trees at 90 and 180 days after kill can be attributed to the lower veneer volume and grade and higher percentage of 4- and 8-foot random width veneer as shown in the tabulation below.

Kill class	Cubic recovery 8-foot block less core	Veneer type C & better full width	8-foot random	4-foot random
Days	*Percent*	*Percent of total*		
0 + 45	47.66	37.14	33.25	4.53
90 + 180	42.28	27.12	42.55	8.56

Table 2—*Dry planed lumber grade recovery data for beetle-killed timber by crown condition and location in the tree.*

	Green		Green-fade		Red		Red-thin		Black	
	Butt	Upper	Butt	Upper	Butt	Upper	Butt	Upper	Butt	Upper
					Percent					
Boards (1-inch)										
No. 1	23.9	5.4	2.6	6.4	10.7	3.9	1.2	4.7	1.3	2.1
No. 2	64.9	71.8	86.5	72.6	57.3	73.5	61.1	50.8	59.8	49.5
No. 3	6.8	20.9	4.7	16.2	23.1	22.6	15.4	34.7	9.0	22.8
No. 4	4.4	1.9	6.2	4.8	8.9	—	22.3	9.8	29.9	25.6
Dimension (2-inch)										
No. 1	54.8	21.3	61.2	32.3	58.1	36.0	41.2	15.6	40.2	22.5
No. 2	30.9	55.6	29.4	41.3	25.7	56.1	28.4	52.7	22.7	39.4
No. 3	8.4	16.9	3.3	14.4	5.9	5.6	6.9	21.5	2.6	6.1
No. 4	5.9	6.2	6.1	12.0	10.3	2.3	23.5	10.2	34.5	32.0

Reduction in the amount of full-width veneer and increased amounts of random-width veneer translate into higher veneer processing costs for SPB-killed timber in the 90- and 180-day kill classes.

The lower initial moisture content of veneer from beetle-killed timber in combination with the increased permeability (due to effects of blue-stain fungi) results in overdried veneer when dried at normal green veneer schedules. Glue-line quality tests indicate that normal drying schedules, adhesives, and gluing practices may require modification to process beetle-killed timber. As pointed out earlier, best results could be achieved if veneer from SPB-killed timber could be segregated and processed separately. This special handling would be justified if a sufficient volume of SPB-killed timber were processed.

Pulp and Paper

Studies have shown that pulp yield dropped very little from beetle-killed pines dead up to 12 months in east Texas and up to 24 months in Virginia.[5] Under proper processing methods, pulp yield differences between green and beetle-killed timber are minimal. However, special problems are created when processing dry, beetle-killed timber into pulp chips due to greater energy requirements at the chipper and the creation of more fine particles. Nonuniformity of chip sizes means that cooking conditions need to be adjusted to produce the right kind of pulp. The low initial moisture content of chips is an obstacle to achieving uniform pulp. Dry chips require higher levels of alkali to reach the same screened yield and reduce the lignin content to the same level as that of pulp from fresh green wood. Achievement of uniform pulp treatment would require a change in operating techniques during digestion such as chip presteaming or a vacuum pretreatment cycle.

[5]Westbrook et al. (1981).

Comparisons of handsheet strength properties from Kraft pulp made from Class A and Class B beetle-killed wood indicate poorer burst, tear, and tensile strengths than from healthy woodpulp. Hitchings and Levi (1981) reported losses in tear strength of 30 to 35 percent for Class B chips. Burst and tensile strength levels were reduced by 20 to 25 percent from those of healthy material.

Composite Products

Particleboard—Research by Kelly et al. (1982) has shown that boards prepared from SPB-killed trees dead for 30 months in western North Carolina had bending, internal bond, screw withdrawal, hardness, water absorption, thickness swelling, and linear expansion properties similar to those of boards manufactured from healthy pine trees. All properties except linear expansion met industry specifications. Particleboards made from beetle-killed trees were darker in color than boards made from healthy trees. The difference was attributed to the blue staining of the beetle-killed wood.

Hardboard—Kelly et al. (1982) also reported that hardboard produced from beetle-killed trees was slightly inferior in quality to that from healthy trees. However, as with particleboards, linear expansion was the only property failing to meet industry specifications. When 50 percent of the fiber furnish came from healthy trees, the hardboards met specifications.

Reconstituted panels—Research has shown that composite products with flakeboard core and veneer faces can be made from beetle-killed timber. Koenigshof et al. (1984) reported that the only variables affecting performance of reconstituted panels made with oriented flake board cores were the density of the core and the resin level used in its construction. Panels were made from beetle-killed trees where deterioration class varied from "just attacked" to "having lost all needles and small branches." No deterioration class nor proportional mixes of flakes made from the various classes were detrimental to strength, durability, or moisture swelling properties of the panels.

Specialty Products

The presence of blue-stained sapwood in beetle-killed trees presents no special technological problems in the manufacture of paneling, and the wide range of "character" marks in heavily deteriorated beetle-killed pine makes it attractive to many users for decorative purposes. Blue-stained paneling made from beetle-killed pine wood is now being manufactured and marketed successfuly (fig. 7). Although SPB-killed timber can be used for paneling, there are certain limitations to such use. First, the wood must be strong enough to survive the handling, sawing, and planing throughout the processing stages. Second, air drying is not sufficient to control woodboring beetles still alive in the tree at the time of harvest. The wood, therefore, must be kiln dried to temperatures higher than 180°F to assure an insect-free paneling product. The finished paneling can be left in its natural state or receive standard stain or varnish treatments.

Firewood

The demand for wood for use in home fireplaces and woodburning stoves has increased in recent years. It has long been believed that using southern pine as a fuel source for

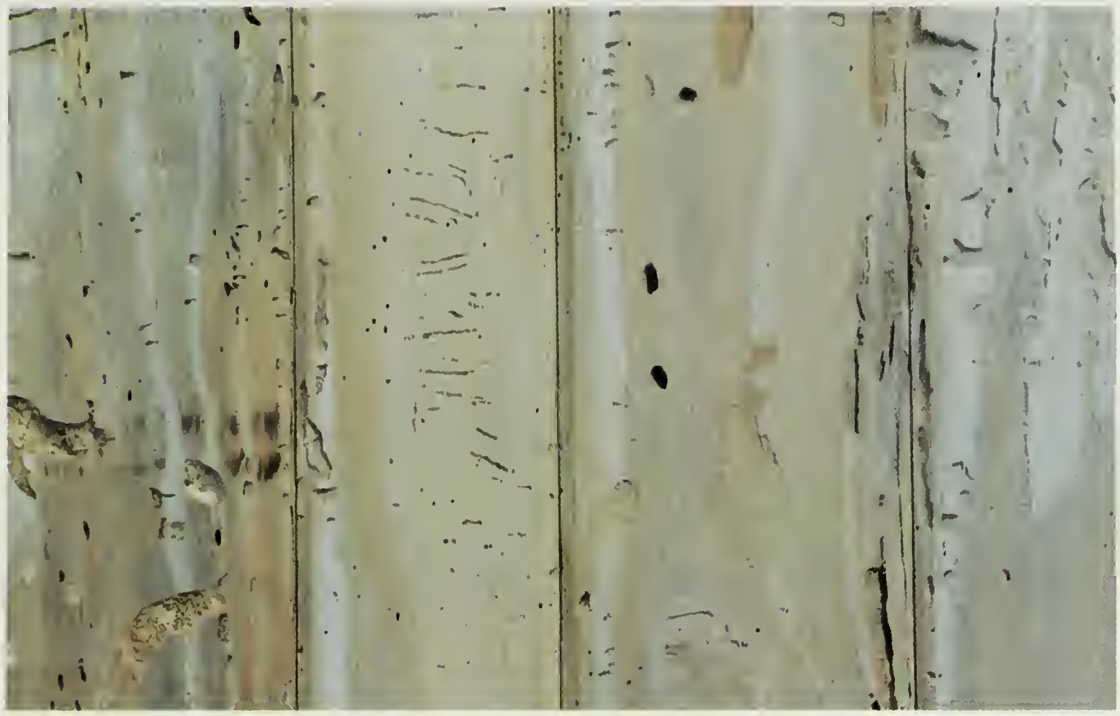


Figure 7—Paneling from southern pine beetle-killed trees.

woodburning stoves produces excessive amounts of creosote. It is also commonly believed that the moisture content of the wood contributes to creosote production. Southern pine, therefore, has been generally rejected as a fuelwood for woodburning stoves. Allen and Maxwell (1982) studied the creosote production of beetle-killed pine and compared the results with those for green pine and hardwoods (seasoned and green) in the following tabulation:

Wood type	Lbs creosote	
	Per ton fuel	*Per ton dry wood*
Beetle-killed pine	4.67	6.21
Seasoned hardwood	3.69	4.27
Green hardwood	2.59	3.73
Green pine	1.73	3.21

Although these results indicate that beetle-killed pine produced the greatest mass of creosote per ton of dry wood, their study concluded that the major factor controlling creosote production was the amount of air provided to the combustion process rather than the type or condition of the wood burned.

SAMTAM Utilization Guidelines

Increasing costs for personnel, material, and equipment have placed increased emphasis on more efficient processing in the sawmill. A sawmill manager must be aware of the profit or loss received from processing logs of various grades and diameters. This is important in day-to-day operation, but becomes increasingly so during beetle outbreaks when there is an abundance of large-diameter, low-cost raw material. To increase the utilization of beetle-killed timber, it is important to know how the profit or loss is affected by processing material at various stages of deterioration. Sawmill analysis models for green and beetle-killed timber developed at Texas A&M (known by their acronyms SAMTAM and SAMTAM II) (Massey et. al. 1983) provide information to help a mill manager determine whether it is profitable to process logs of different grades, sizes, and (in the case of beetle-killed timber) kill class (time since death). SAMTAM is the model for green logs only, SAMTAM II for both green and beetle-killed logs.

Both models provide two quality control checks (sawing variation and log overlength), three recovery efficiencies (LRF, overrun, and product percentages), and two profit or loss analyses (actual log data and smoothed predictions).

The models are designed to provide the following information:

1. Average rough green size for each lumber size class. The standard deviation and the range (which will include 95 percent of the measurements) are determined for each size class.
2. A prediction equation for log sawing time.
3. Data on:
   - (a) The dollar value of sawdust, chips, shavings, bark, and lumber by individual log.
   - (b) The percentage of green log cubic volume in sawdust, chips, shavings, dry lumber, and green lumber by individual log.
   - (c) The board foot recovery, log scale, overrun, cubic volume, and LRF for each log.
   - (d) The log grade, scaling diameter, length, total volume, total cost, and profit or loss for each log.
4. Tables giving the value, cost, and profit or loss for each diameter and log length by USDA Forest Service log grade for SAMTAM and by kill class for SAMTAM II.

A schematic of the input/output for SAMTAM II is illustrated in figure 8. The information given by SAMTAM II should be more appropriate to conditions in the mid-South because the residue volumes are based on the actual lumber sawn, the density value is assigned from a distribution function based on data collected in east Texas sawmills, and the kill classes and their respective moisture contents and bark volumes are based on trees from east Texas.

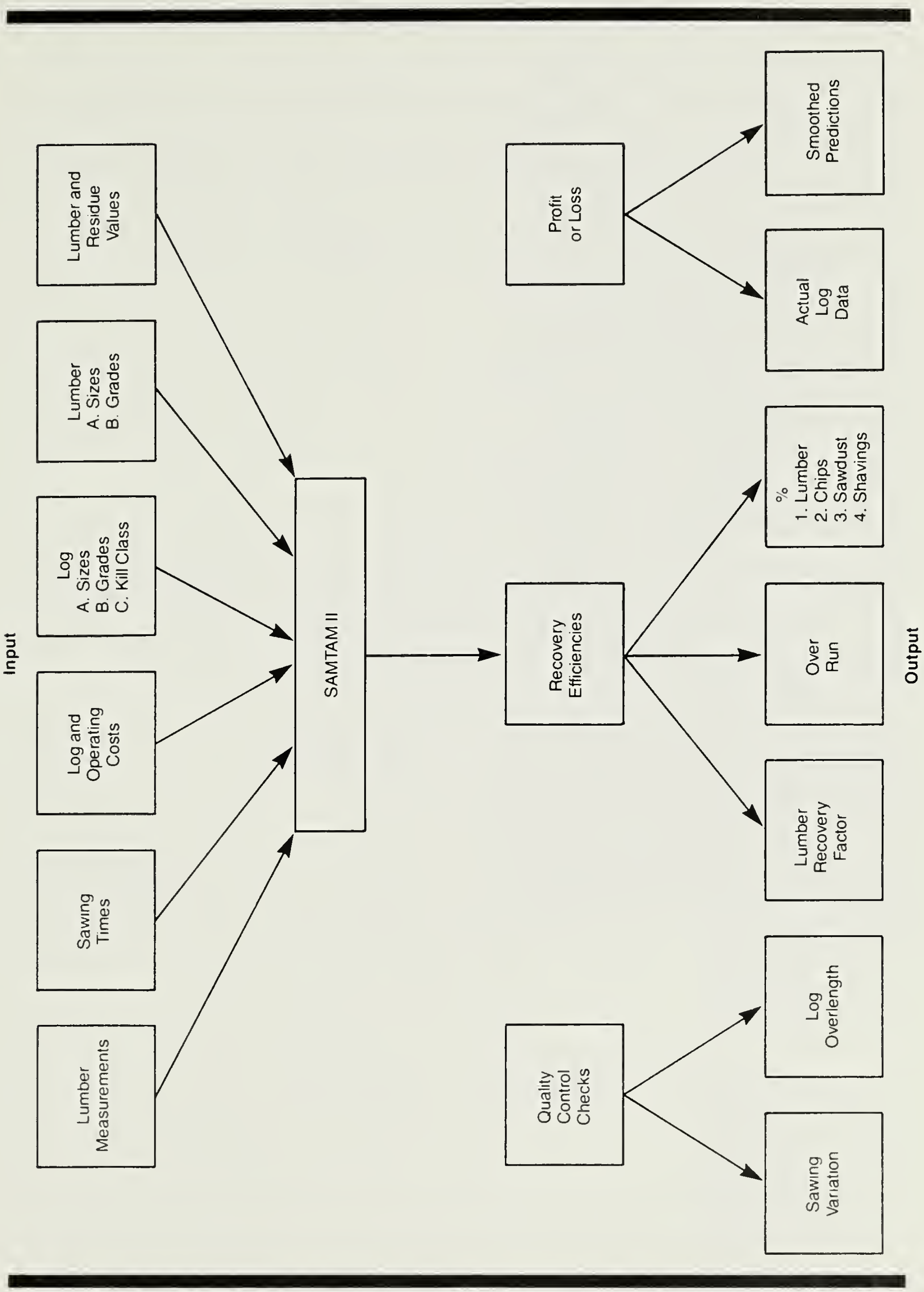


Figure 8—Schematic of input/output for Texas A&M sawmill analysis model (SAMTAM II).

Conclusions

Up to now, beetle-killed timber has been underutilized because its value has been misjudged. Reluctance on the part of timber buyers to use such material has left mill managers with the option of either suppressing prices or refusing to process this type of wood. But recent research has shown that beetle-killed pulpwood and sawtimber can be utilized for a wide variety of wood products (table 3) if trees are harvested and processed soon after attack. Lumber grade in beetle-killed trees is lower than for healthy ones, but yields of particleboard, hardboard, and pulp are similar for both types. In addition, a lower moisture content makes beetle-killed pine an economical purchase for those who buy wood on a weight basis, since it yields more fiber per dollar than healthy pine. The development of the SAMTAM and SAMTAM II sawmill analysis models now takes the guesswork out of profit and loss determinations in processing beetlekilled logs and can make their increased utilization an attractive option for many wood products.

Table 3—*Utilization guidelines for beetle-killed trees*[1]

Product	Class A	Class B	Comments
Lumber—appearance	Not recommended	Not recommended	Blue-stain prohibits use.
Lumber—dimension	Can be used with caution	Not recommended	Should be kiln dried to prevent emergence of secondary insects. Low moisture content may dull saws and chipper knives faster than with sound wood and may require milder kiln schedule. Do not use where toughness is important.
Lumber—decorative boards and paneling	Can be used	Can be used	Should be kiln dried.
Posts, poles, piling	Not recommended	Not recommended	Toughness and preservative treatability may be highly variable.
Plywood	Can be used	Not recommended	Adhesives and gluing practices may have to be adjusted.
Hardboard, particleboard, medium-density fiberboard	Can be used	Can be used	Low moisture content may affect some production schedules. Should be mixed with sound wood.
Pulp	Can be used	Can be used	Blue-stain and low moisture content may affect pulping process and chemical or energy requirements. Should be mixed with sound wood, particularly where strength is important.
Fuelwood	Can be used	Can be used	Low moisture content increases heat value.

[1]Source: M.P. Levi, 1981.

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